2-5-15. Mechanochromic Materials

Overview

Mechanochromic materials change color in response to mechanical stimuli (e.g., grinding, compressing, and stretching) and revert to the original color after removal of the stimulus or upon application of a secondary stimulus such as heating or solvent exposure (Fig. 1). Photoluminescence color change is called mechanochromic luminescence (MCL). Research has advanced across diverse systems, including organic and organometallic crystals, liquid crystals, and polymers, and applications in next-generation pressure sensors and anti-counterfeiting technologies are anticipated.

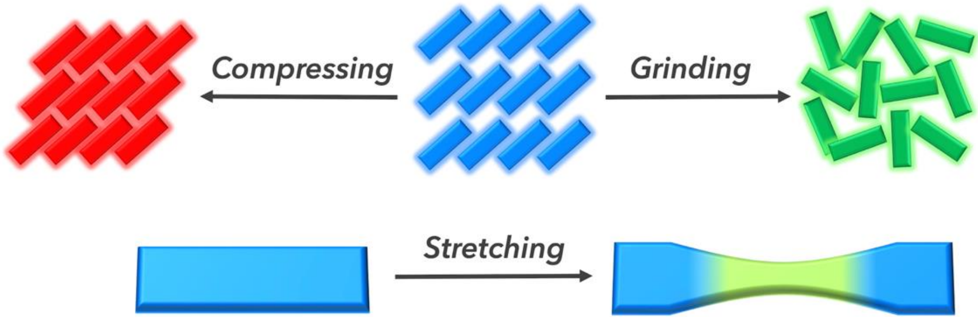

Figure 1. Mechanochromic materials that change color under mechanical stimuli.

Current Status and Frontiers

Chromism is the reversible color change in response to external stimuli, and changes induced by mechanical stimuli are called mechanochromism. Since the 1990s, studies have focused on materials using the structural color of photonic crystals or shifts in the absorption of dyes incorporated into polymers. A pyrene derivative (Araki *et al.*, 2007) and a gold isocyanide complex (H. Ito and Sawamura *et al.*, 2008) were found to change emission color upon grinding, which initiated the rapid growth of MCL research.

In crystals of organic and organometallic compounds, mechanical stimulation can induce amorphization or phase transitions, leading to different emission colors. Although red-shifted MCL is common, blue-shifted MCL and two-step MCL have also been increasingly reported (Fig. 2). While typical emission shifts are <150 nm, considerably larger shifts have been observed, for example in an aminobenzopyranoxanthene derivative (Kamino, Muranaka, and Enomoto) and an anthryl gold isocyanide complex (Seki and H. Ito). As a strategy to regulate the behavior, mixing two emitters has been proposed (S. Ito and Tachikawa). Moreover, MCL based on thermally activated delayed fluorescence (Takeda and Minakata), room-temperature phosphorescence (Tani and

Ogawa), and circularly polarized luminescence (S. Ito and Imai) have been developed.

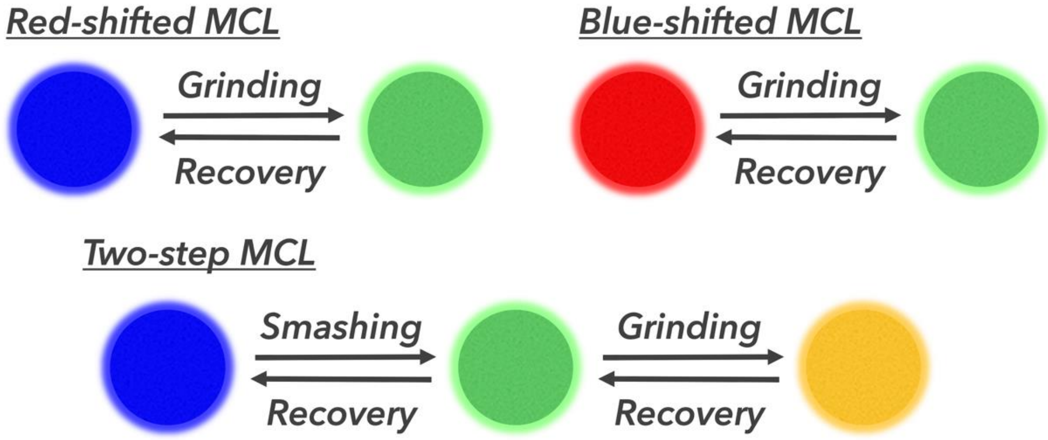

Figure 2. Representative behaviors of mechanochromic materials.

Changes in absorption and emission spectra under hydrostatic pressure are also regarded as mechanochromism, although they are more specifically termed piezochromism. Piezochromic luminescence has been extensively studied in organic and organometallic crystals, including a crystal that display different colors under anisotropic grinding and isotropic hydrostatic pressure (Saito and Yamaguchi *et al.*).

In polymers, research has advanced on mechanochromic materials with colorimetric and fluorescent mechanophores based on dynamic covalent bonds (Otsuka *et al.*) and with rotaxane- and cyclophane-based supramolecular mechanophores (Sagara *et al.*).

References

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5. S. Ito, S. Wakiyama, H. Chen, M. Abekura, H. Uekusa, R. Ikemura, Y. Imai, *Angew. Chem. Int. Ed.*, **64**, e202422913 (2025).

Future Perspectives and Directions

Key challenges for the next 10 years: prediction of mechanical responsiveness from molecular and crystal structures; detection of stimuli at the single-molecule level; creation of large-area materials; practical applications in pressure sensors and anti-counterfeiting.

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